THE PROBLEM OF FATIGUE.

By WILLIAM H. BURNHAM.

Hygiene is sometimes called the science of the future. Perhaps the same is true of psychology. However that may be, its doctrines at the present time are largely in the form of problems. This is encouraging; for in the field of science a definite ignorance is the beginning of wisdom.

The whole subject of work and fatigue among school children has been studied by many investigators for twenty years or more, and the outcome of it all is a series of tolerably definite problems. The general problem of fatigue involves, on the one hand, many physical factors, on the other hand, many psychological factors, and also the relation of these two sets of factors. The relation of fatigue to the various psychic factors, —such as practice, warming up, habituation, voluntary effort, and the like, has been carefully studied by Kraepelin (8) and the complexity of the problem has been well shown by Dr. Bolton. (2.)

From the physiological side the problem of work and of fatigue has thus far been treated by most writers as if the human organism were practically a complicated and delicate machine whose working is affected by its environment as regards temperature, humidity, etc., by the overcoming of friction and its own inertia, by periods of rest to avoid over-heating of parts, by suitable oiling, cleaning, etc., but whose ultimate output of energy is determined by the fuel it consumes. The nervous system has been likened by Dr. Donaldson (3, p. 293) to an engine. The analogy is a good one for its purpose. But the psycho-physical mechanism has a power of adaptation not possessed by any machine. Especially is this true during the period of growth and development. Thus the problem for the work of children seems to be almost hopelessly complex, because within certain limits the power to resist fatigue can be acquired. Very likely as suggested by Weichardt's (19) investigations this is due in part to an acquired immunity to the toxic products of fatigue; but whatever the cause of it the fact seems to be shown.

The problem is still further complicated by the fact that the amount and quality of brain work that can be done is determined by many conditions. Among the most important of

these are the following: Race, sex, physiological age, food, drugs, sleep, temperature, light, air, season and meteorological conditions, exercise, posture, health conditions, refraction of the eyes, conditions of hearing, nasal breathing, and the whole mental attitude or apperception.

The problem of work and of fatigue in simple form is that of determining what periods of work and rest will enable an individual to do the maxium amount of work within the limits of health, whether the work be physical or mental.

It is not easy for an individual to settle this question for himself. For a group of individuals the problem is still more complex on account of the remarkable individual variations in ability which all investigations show, and for a group of individuals in the period of growth and development the complexity may fairly be called infinite. Nevertheless, it is a question that must be answered every day in the study and in the schoolroom, and so we cannot shirk it on account of its difficulty.

The problem presents itself in concrete form in testing a muscle or a group of muscles in the laboratory. One can determine just what rhythm and what alternation of work and rest will enable a group of muscles lifting a given weight to do the maximum amount of work. The problem here is not so simple, however, as it at first appears. One of the most striking results of the early experiments with the ergograph by Dr. Lombard (10) was the periodic recovery of the muscle. Contracting the muscles of his middle finger till it was no longer possible to lift the given weight, this investigator found that if he continued the effort, presently the muscles responded and the weight could be lifted nearly as high as before; and this loss and return of power occurred several times. This recovery Dr. Lombard likened to certain phenomena of periodicity shown in ordinary life, such as the second breath of the runner; and he attributed it to central causes. Recent experiments by Treves (16), however, indicate that this phenomenon of periodicity can be obtained by electrical stimulation of the muscles, and consequently it is referred by him to peripheral rather than central causes. It seems probable that the cause of this periodic recovery is to be found partly in the nerve centres and partly in the peripheral apparatus, that when it occurs under ordinary conditions of stimulation both central and peripheral causes combine to produce it. While Treves (16) has shown that these phenomena may be produced by peripheral stimulation alone, as Dr. Bergström (1) has said: "This does not, however, show that changes in force, even rhythmic changes, may not also occur in the nerve centres stimulating the muscle." Whether this recovery is due to central causes as supposed by Lombard (10), or to peripheral causes as maintained by Treves

(16), or partly to changes in the nerve centres and partly to changes in the periphery as suggested by Bergström (1); and whether the physiological causes are changes in nutrition, or the results of an antitoxin, or some unknown factor, the phenomenon suggests the possibility of extending the limits of the functional activity of a set of muscles and even of one's working capacity in general. But how far and in what way it may be safe to attempt this, we do not know.

At all events the factor of training must be reckoned with, and this in itself presents a very complex problem. The difference between the trained muscle and the untrained muscle is not merely a difference in size and nutrition. Professor Hough (5) has shown that in case of the untrained muscle the fribrillæ are lacerated by exercise—hence the soreness that results. In the trained muscle this tearing does not occur. Also a very complex process of adaptation or habituation is involved. To quote Dr. Bergström (1, p. 273) again: "A certain class of psychic factors certainly affect the records; competition and encouragement often greatly augment both momentary strength and endurance, and discouragement or a sense of failure may produce the contrary effect. By pretending to present a subject with a series of increasing loads, successive reductions in the record may sometimes be observed, while as a matter of fact the load remains constant. Habits of effort, like habits of sleep, may no doubt exist or be established by training, and even variations like the Lombard curves are not impossible from such a source, but might be due to overcoming a reflex tendency to rest, just as we may by persistent effort counteract a tendency to fall asleep." Even on the physical side the problem is a complex one. The problem of training is closely related to that of immunity; and it will be helpful briefly to consider the latter.

When certain poisons are introduced into the animal body, nature at once proceeds to manufacture an antidote, and if the amount of poison introduced at any one time is not too large, the antidote is usually sufficient to correct its effect. This has been illustrated very vividly in modern therapeutics.

The modern discovery of antigenes and anti-bodies has revolutionized the treatment of many diseases. Antigenes are substances of unknown chemical composition which act as stimuli for the production of anti-bodies; and anti-bodies, not to attempt a technical definition, are substances which act as antidotes to certain poisons, or as checking agents upon the antigenes. The toxin and antitoxin of diphtheria furnish the standard illustration. If the toxin of diphtheria is repeatedly injected in proper quantities into the blood of a horse, this stimulates the production of an anti-body, which can be taken from the veins

of the horse and used as a remedy. Thus is produced the antitoxin for diphtheria, which during the last dozen years has so enormously reduced the mortality from this disease.

In a similar way are produced antitoxins for a number of diseases: for tetanus, for dysentery, for the poison of snakes, etc. But it is not only in disease that such anti-bodies are produced (19), and not merely the poisons that act as antigenes in producing these bodies. Antiurease, antitrypsin, antipepsin, and the like, belong to this same group of anti-bodies occurring in the normal animal.

In tuberculosis we have an interesting illustration, apparently, of the general law of immunity. It is estimated that one-seventh of the total mortality results from this disease; but a vastly larger number have been afflicted with it. Dr. Flexner estimates that at least 90 per cent. of the total population have been subject at one time or another to tuberculosis. This has been shown by the results of innumerable autopsies. The resistance to the disease, however, is so great in most people that it has been cured or arrested. Again, the most successful experiments in the treatment of tuberculosis in animals have been those of direct inoculation with tubercle bacilli, thus developing immunity,

Acquired resistance to fatigue seems to be also a case of immunity. It was apparently proved by Mosso that toxic products result from the functional activity of the muscles and that these are the chief cause of fatigue. Thus when the blood of a tired dog was injected into the veins of a normal one the latter showed the symptoms of fatigue. If Weichardt's studies (18 and 19) are to be credited this is only half the story. His results not only corroborate Mosso's theory of a fatigue toxin, but have also shown apparently the existence of certain anti-bodies that produce an antitoxin of fatigue. From his remarkable experiments with mice this investigator reports that when a mouse was worked to exhaustion he found a toxin produced in the muscle serum. This purified from salts, creatin, urea, and albumen, and injected into another mouse caused fatigue, and in large doses death. When a horse was treated with frequent injections of this purified serum an antitoxin was formed which acted as an antidote to fatigue.

Weichardt (19) has made many experiments with this toxin and antitoxin of fatigue. With the artificially produced fatigue toxin all the characteristic symptoms of fatigue, even death from exhaustion, are produced. On the other hand, he has also succeeded in neutralizing the effect of the fatigue toxin by means of the artificially produced antitoxin.

The discovery of fatigue toxin in the excreta of the body and even in human urine shows that the formation of toxic

products occurs in ordinary physiological fatigue, and that extreme pathological fatigue is not necessary to produce this toxin. The antitoxin also, not only may be produced artificially in the manner just mentioned but is produced during normal functional activity. With the appearance of moderate quantities of the products of fatigue there always occurs in the healthy organism an increased formation of the specific antitoxin, *i. e.*, there is always the tendency to develop immunity to fatigue.

This has been shown by Weichardt (19) in his experiments with mice. The normal curve of work for a mouse is similar to that of a man as shown by the ergograph. If the mouse is treated with an injection of a moderate dose of toxin the curve of work is somewhat raised, and then sinks only slowly after a prolonged period. The reason for this is that a moderate dose of the fatigue toxin works as an antigene and produces the antitoxin in increased quantity, thus enabling the animal to do more work. If, however, the mouse is given a large dose, so that the cells which produce the antitoxin are injured, the ability to work is decreased; or, if the dose be sufficiently large, the animal soon dies from the effects of it. If, however, mice which beforehand have been treated with the antitoxin are given a large dose of toxin a continuous curve of work is produced. The curves of men, who have been trained in the use of the ergograph, correspond to the curves of mice treated with the antitoxin. Of course, the human subject cannot be treated with a large dose of the toxin; but the stages of increased ability to work, *i. e.*, the stages of active immunity brought about by the stimulus of small doses of the toxin, are shown. In other words, the process of training is not a mere process of modification and increase of muscle tissue, it is also a process of rendering the subject immune to fatigue. In the trained subject the ability to work is increased as a result of increased power to resist fatigue.

One is at first inclined to think that Weichardt's (19) study is another case to be added to the long line of discredited investigations in this field. But whether his results stand the test of further experimentation or not, the problem of fatigue is not misrepresented by them. It is in part the problem of adaptation or immunity. And for the present we may naturally conceive of this as analogous to the immunizing contest in infection as represented by the hypothesis of Dr. Welch:[1] "The struggle between the bacteria and the body cells in infections may be conceived as an immunizing contest in which each participant is stimulated by its opponent to the production of

[1] As cited by Ricketts in "Infection Immunity and Serum Therapy". Chicago, 1906, p. 567.

cytotoxins hostile to the other and thereby endeavors to make itself immune against its antagonist."

Of course, all of this applies primarily to muscular fatigue, but it is probably true that the conditions of fatigue resulting from mental activity are similar and that within certain limits immunity to fatigue may be developed, or in psychological terms, habits of increased ability to work may be formed. This was pointed out some years ago by German writers. Dr. Erb (4, pp. 26-27) for example writes:

"The nervous system in its comprehensive mode of habit and adaptation is capable of increased exertions as well as able to endure greater injuries, as von Ziemssen recently has shown in an interesting manner. . . . Just as our senses become accustomed to all possible impressions so that they pass almost unnoticed, so also the brain will gradually learn to accustom itself to all the daily injuries which beset it, to the noise, the hurry, and unrest, the mechanical shocks in our everyday life and business. It will be more difficult to be sure with the psychic shocks, the excitements and emotions, but even here, habit, training of character, and self-control can certainly do very much; and thus we have good prospect that our nervous system will adapt itself, to a certain degree, to the demands placed upon it by our culture of to-day and by habituation neutralize their injurious effects."

The relation of the mental factor to fatigue likewise presents a very complex problem. It has been briefly stated by Dr. Seashore as: "The correlation of psychological and underlying factors, such as physical, chemical, histological, and electrical phenomena. If the attention wave varies with fatigue, as Prof. Pillsbury has demonstrated, we may ask, what are the physiological factors which condition that variation? What feature in the mental work is it that causes the physiological state? What chemical processes may be traced? What is the cell modification? Are there any characteristic electrical variations?"

Again we have the great problem of the relation of one kind of fatigue to another and whether there is one reservoir of energy or several. It has frequently been noted that change of occupation is a means of rest. The child tired with school work turns with enthusiasm to his play; and even a game requiring close attention or an interesting book is taken up with a zest which indicates that the interesting occupation is rest from the routine of study; and the man of business weary with the work of the day turns at night to the study of some engrossing fad and finds it a means of rest and recreation. Mosso (11, p. 120) in his book on fatigue says: "Apparently the fatigue is localized only in a certain region of the brain; for one often sees

persons who have become incapable of thinking about a certain subject or considering a matter of business find recreation in thinking of something quite different, or even rid themselves of a feeling of pressure in the head by turning their attention sharply to other things of a different character, for example, to chess playing."

Weygandt (20) working in Kraepelin's laboratory, has studied this question. His problem was this: does change have a favorable or unfavorable effect upon the amount of work done? He employed Kraepelin's method of adding varied with several other forms of activity,—learning by heart of numbers and nonsense syllables, the search for a definite letter in a connected text, reading of a foreign text of different kinds, —Latin, Italian, Hungarian, Hebrew, the writing down of a known series of letters, and finally, a series of experiments with complete pauses instead of change of work. Almost all these methods were used for the chief work as well as for the change of work. Of the different methods, adding predominately appeals to the associative processes; the learning of numbers and syllables to memory; the reading methods involve perception and assimilation. First, he worked for one day at a definite form of activity for one hour and a quarter; then on the next day he worked for the first half-hour at the same form of activity, this determining the character of the day's work; then followed a change taking up another definite activity, for half an hour; then again for fifteen minutes he worked at the original activity to determine the effect of a change on the amount of work done. These experiments extended over some 97 days of experiment, the usual control of conditions being adopted.

As a result of these experiments, it appears that change of the method of work is not under all circumstances favorable. Often the result is positive, often negative, but usually only very slight. Second, the difficulty of the work appeared as a determining factor in the result. A form of work broken by a more difficult form of work shows thereafter less results than would be expected; broken by a lighter form of work, on the other hand, shows better results. Third, it is all the same whether the mental work that alternates with another is of similar or dissimilar character. In a word, the result of his investigation furnishes no evidence for the assumption of a partial and localized mental fatigue. And Kraepelin (8) interprets his results as indicating that fatigue is general. "Fatigue through mental work is," he writes, "so far as we know, a general fatigue. As especially Weygandt's study on the effect of change in mental work has shown, the fatigue through a particular activity also reduces the capacity for such work as is brought about

through quite different mental activities. Thus the necessity of rest and sleep arises at certain times regardless of whether the same or changing work has provoked it. Only the difficulty and not the kind of mental work is significant for the general extent of fatigue."

Dr. Seashore thinks that Kraepelin is wrong in this and he reports experiments in Iowa laboratories that have demonstrated that the kind and degree of fatigue both depend upon the kind as well as the degree of mental exertion. It seems to be still a problem whether there is one reservoir of nervous energy or many reservoirs, or in other words whether fatigue is always general fatigue, one and the same, or whether it is often local fatigue. There is some reason for believing that there may be a difference between children and adults in this respect, one reservoir representing more nearly the fact for the unorganized system of childhood.

It would seem at least that the popular idea that change of work means rest, and the pedagogical maxim emphasized by Richter (13) as the result of his experiments with school children in occupations similar to those of the ordinary school work, must be modified. The fact probably is that in the more ordinary cases it is not fatigue which is appreciably lessened by change of work but rather the feeling of boredom, the ennui, the *Müdigkeit* not the *Ermüdung*, as Kraepelin (8) distinguishes the two. In the more extreme cases, as illustrated in the case of the exhausted soldier who arouses himself to renewed activity in a crisis, or the experimenter in the laboratory who exhibits the phenomena of recovery, or the runner who gets his second breath,—what happens is probably that a new store of energy is in some way set free; and, although the feeling of fatigue has disappeared, fatigue itself may have been increased and the ultimate ability of the organism to work diminished. But definite results are lacking and more experimentation is needed.

Professor James (6) has recently studied many of the phenomena similar to those of second breath, and concludes that our organism "has stored up reserves of energy that are ordinarily not called upon, but that they may be called upon: deeper and deeper strata of combustible or explosible material, discontinously arranged, but ready for use by any one who probes so deep, and repairing themselves by rest as well as do the superficial strata. Most of us continue living unnecessarily near our surface."

He reports many interesting cases where old habits of performance have been broken up and an astonishingly increased capacity for work developed. Among the dynamogenic agents that he has studied are the training of the Yoga system, Christian Science, and the like, religious, political, philo-

sophical, and scientific conversions, and among more concrete energy releasing ideas, "Fatherland," "the flag," "the Union," "Holy Church," "the Monroe Doctrine," "Truth," "Science," "Liberty," Garibaldi's phrase "Rome or Death," etc.

This investigation opens the deeper problems of neural economy. That there are many such cases as those cited by Dr. James (6) cannot be doubted. Further study may show that such cases fall into widely different classes. Some of these are probably pathological. An abnormal activity is aroused, the subject may perhaps kill himself or become a wreck in a few years. Most of them, however, are perhaps normal and, as suggested by Professor James (6), they frequently represent the cure of nervous disorder. In some cases the great improvement in the individual's productive activity may be brought about merely by stopping waste. It is astonishing how much this amounts to in the case of many persons. Every one in his experience has the opportunity to note the great economy of co-ordinated activity and the extreme waste when confused, or nervous, or "rattled." Some persons work without waste excluding all interference of association and all unessential movements when under pressure. Others are made nervous by undue pressure and work most economically when at leisure. When hard pressed they are nervous and confused, when at ease they make no false motions, have no interference of association, and work directly and economically. In both classes the great improvement in productive activity is brought about by the same means, namely, the stopping of waste.

In other cases the great improvement in productive activity may be due to an improvement in nutrition, more energy is stored up, and thus the amount of energy available for work is increased. This improvement may be brought about in two ways: First, the checking of worry and habits of emotional prodigality by working under a strong stimulus is quite enough in many cases greatly to modify and improve, it may be, all the nutritive functions of the body; and this in some cases may be the chief factor.

Again, the nutrition may be greatly improved perhaps in a very different way. It seems probable that the nervous system functions rhythmically; first, a period for the storing up of energy, a period when the anabolic processes predominate; then a period of explosion when the katabolic processes predominate, and so on. Now as is generally recognized a suitable period for the storing of energy is essential in order to give the necessary conditions for the vigorous explosion of energy. It is probably also true, although this seems to have been neglected, that the vigorous explosion of energy is likewise a necessary condition for the proper functioning of the anabolic

processes that predominate in a subsequent period of rest. Verworn's (17) hypothesis that after exercise there is not only the restoration of what has been lost but an over-compensation is in harmony with this view.

Thus in some cases the improvement in nutrition is probably caused by the fact that the vigorous explosion of energy due to a strong stimulus has furnished the one essential condition for the functioning of the nutritive processes on a higher level. Thus in certain conditions excitement and the explosion of energy may be as essential as rest and the storing of energy.

Again, this theory is in harmony with the results found by Professor Patrick (12) in his study of sleep, referred to by Dr. James (6). After one subject had been kept awake for over 90 hours, 13 hours of sleep seemed to be enough to restore him to normal condition. This was explained in part by Professor Patrick on the theory that the rate of repair was increased, the anabolic processes were so stimulated that the short period of sleep was all that was needed. In these experiments the essential condition of the increased nutrition seemed to be the increased expenditure that had preceded. In ordinary sleep also we have an illustration of the same phenomenon. Frequently the condition of sound and refreshing sleep seems to be the normal exhaustion that results from vigorous activity during the day, a fact that has been observed since the days of Solomon: "The sleep of a laboring man is sweet whether he eat little or much."

Another factor which probably accounts for some of the increase of work in such cases is the development of immunity to fatigue, perhaps to the toxic products of fatigue, as suggested by Weichardt's (19) experiments.

In certain instances, perhaps in most, all of these factors combine to produce the increased efficiency of work. In most of the cases probably a better habit of functioning is the secret, but this involves better nutrition and very likely the acquisition of immunity.

The study of the neurasthenic is instructive. The characteristic symptoms are too familiar. They are chronic fatigue, inability to perform any continuous task, lack of energy for any vigorous action, and also irritability, restlessness and a continuous dribbling out of energy. If the hypothesis already suggested be true, then this condition may be due to any one of three causes.

First. The individual may never have developed any considerable amount of nervous energy. He may be one of those, as suggested by Tissié (15), who are born in a condition of fatigue. The nervous system may be undeveloped so far as its trophic functions are concerned.

Second. The individual may have a nervous system that is normal, but may never have been stimulated to any vigorous explosion of energy, consequently a necessary condition for the proper storage of energy is lacking. Such probably, as already suggested, are some of the cases cited by Dr. James (6), and the remarkable results of the Yoga system, the emotional stress of conversion, or of falling in love, or what not, are due to the fact that thus a vigorous expenditure of energy was caused and this provided the one essential condition lacking for the normal storing of energy. In such cases we may conclude that a strong stimulus or shock of some kind is the thing needed.

Third. In another class of cases the individual has seriously over-taxed himself. The nerve cells have perhaps actually been injured so that normal recovery is temporarily at least impossible. In such cases what is needed first of all is rest. To ignore this condition and attempt to cure by further work, by greater stimuli and the like, would be useless and perhaps fatal.

We are not concerned here directly with the practical questions of therapeutics, but we note that we may have practically the same symptoms with patients of very different nervous conditions and requiring diverse treatment. The practical problem of diagnosis in such cases is no more complex than the hygienic and economic problem of determining the proper quantity and quality of activity. One must know the condition of an individual's nervous system if one is to prescribe a method of work.

Thus the problem of tapping the deeper levels of energy involves the problems of nutrition, of physical and mental adaptation, and of immunity.

Among other important questions which still remain open in this field, are the following:

First. Although it has been shown that certain phenomena like periodicity may be brought about by peripheral causes alone, the question is still unsettled whether the fatigue resulting from ordinary neuro-muscular work is primarily central or peripheral.

Second. It does not seem to be as yet satisfactorily settled whether the nerve centre or the periphery is better able to resist fatigue, although it seems probable that the nerve centre has greater resistance.

Mlle. Joteyko (7) infers from her experiments that there is a hierarchy in the tissues as regards their resistance to fatigue. The nerve trunks appear to have greater resistance according to the experiments of a number of writers. According to Mlle. Joteyko's (7) experiments the reflex centres of the cord

have greater power of resistance to fatigue than the psychomotor centres, and both have greater resistance than the peripheral apparatus. Thus she concludes that in physiological conditions the phenomena of motor fatigue are due to the arrest of function of the intra-muscular nerve endings.

Thus Mlle. Joteyko (7) thinks that she has shown that the origin of fatigue is in the main peripheral and that fatigue plays a kine-philetic rôle, that is, it is a defensive function of movement. One feels inclined to accept the results of this brilliant experimenter; but further investigation of this point is desirable.

Third. The question of the range of individual variation in ability to work and to resist fatigue, and of types of workers, and the like, is suggested as an important one by the studies of Kraepelin (8) and Mlle. Joteyko (7).

Fourth. The problem still remains of finding a good practical test of the psychophysic condition of an individual that can be used by a teacher or a physician to determine whether one is overworked or not. Perhaps it is too much to expect that any simple test of a condition so complex will ever be possible.

Thus the whole problem of fatigue is an infinitely complex one. We are not concerned here with practical inferences from the investigations that have been made. We may add a few words, however, in regard to the relation of the problem to pedagogy. With our present knowledge it is impossible to give an adequate solution of the practical questions involved. One general point, however, is emphasized by the results of these investigations. Immunity to the toxic products of fatigue is probably brought about by gradual habituation to small doses of fatigue toxin. Large doses decrease the ability to work and may do permanent injury. Thus it would seem that the general rule of hygiene is established in correspondence with that resulting from ordinary observation, that the way to develop power to resist fatigue in children is by short periods of intense work followed by periods of rest rather than by prolonged periods of work; and in fact that the latter should be looked upon with grave suspicion as likely permanently to injure the ability to work.

This inference is largely in harmony with the suggestions that come from the observation of cases of the character reported by Dr. James (6). As he suggests from a very different point of view habit and adaptation in conflict with the excitement of emotion are determining factors. "The emotions and excitements due to usual situations are the usual inciters of the will. But these act discontinuously; and in the intervals the shallower levels of life tend to close in and shut

us off. Accordingly the best practical knowers of the human soul have invented the thing known as methodical ascetic discipline to keep the deeper levels constantly in reach. Beginning with easy tasks, passing to harder ones, and exercising day by day, it is, I believe, admitted that disciples of asceticism can reach very high levels of freedom and power of will."

The concrete problems of the schoolroom related to the general problem of fatigue are legion. Teachers may naturally be sceptical of any attempt to solve them by scientific methods. Dr. Lehmann (9, p. 297), a gymnasium teacher, for example writes:

"An exact theory of instruction or of its separate factors of the programme, for example, is impossible because the practical work of teaching must every moment reckon with forces which experiment can neither exclude nor estimate. The pupils are not even for a moment merely heads with the angel wings of the intellect. The personality of the teacher, for example, and the relation of the pupils to him constantly influences the tension and the kind of association of the class. There are not only teachers who fatigue their pupils quicker than others, but also those whose force of suggestion holds them quite in their own power and causes them to overcome fatigue for a relatively long time. But if one seeks to estimate the personality of the individual teacher or the character of the pupils by making the experiment with a very large number and accordingly gets very large figures, the results obtained may still be of value for theoretical psychology, but for pedagogy and for the practical work of instruction they are worthless."

While this distinguished German teacher is right that no exact rules can be developed in this field, he is not to be understood as deprecating the scientific study of the conditions of school work. And probably the value of such study in emphasizing the complexity of the problem, in making definite the knowledge we already have, and in mediating between conflicting opinions, will amply reward investigation. Moreover, in such problems we cannot expect exact information, but the writer believes that more definite practical contributions than most teachers imagine are possible.

At present we are just beginning to see the complexity and the significance of the concrete problems of economy and hygiene in school work. Questions of physiological age, seasonal variation in growth and energy, individual variations in ability to work and to resist fatigue, the conditions of training and of immunity, of sanitary and of social environment, are all involved; and many special studies must be made before definite rules for the optimum conditions of school work can be formulated. And until further investigations have been made

it appears desirable that the practical questions in regard to the period of study, and the like, be solved tentatively, and that different plans be tried experimentally to the end that ultimately a solution based upon scientific data may be obtained.

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